OFFICE COPY

This study was made in accordance with my March 5, 1993 memorandum,

W. Werrell

Park had funds and let contract, Cost was $8,000.

August 23, 1993

# RESULTS OF GEOLOGICAL SURVEY INVESTIGATION AT PINNACLES NATIONAL MONUMENT PAICINES, CALIFORNIA

**Prepared for:**

Superintendent
Pinnacles National Monument
Paicines, California 95043

**Prepared by:**

Fred R. Conwell & Associates
1641 North First Street, Suite 235
San Jose, California 95112
(408) 452-0262

Fred R. Conwell
Fred R. Conwell
Engineering Geologist
CEG 546

William C. Ellis
William C. Ellis
Hydrogeologist
CEG 363

Order No. 1443PX8450-93-0138
RFQ 845093001

# TABLE OF CONTENTS

# RESULTS OF GEOLOGICAL SURVEY INVESTIGATION AT PINNACLES NATIONAL MONUMENT PAICINES, CALIFORNIA

## 1.0 INTRODUCTION

### 1.1 Background and Setting

This report summarizes the results of the geological survey conducted at the Pinnacles National Monument during July and August 1993 under contract with the National Park Service. The objective of the investigation was to: a) conduct a geologic investigation of the area immediately east of Chalone Creek, from the confluence of Chalone Creek and Bear Creek northward; and b) identify the location and dip of the Chalone Creek Fault within and upstream of the confluence of these creeks. Results of this study will be used to evaluate potential test well drilling sites east of the Chalone Creek Fault.

The scope of the work included: compilation and review of previous geological and hydrogeological reports, maps and data; study and interpretation of aerial photography; geological inspection of outcrops in the field; selection of a location to perform a geophysical survey; selection of the most appropriate geophysical survey method to locate the Chalone fault; performing a refraction geophysical profile across the fault trace area; and, preparation of this report. The level of field investigation was reconnaissance in nature, except for the geophysical profile, which was conducted to an advanced degree of detail.

The geological work was performed by Fred R. Conwell and William C. Ellis, registered geologist in the State of California. The geophysical work was performed by James Rezowalli, registered geophysicist in the State of California.

Basically, Chalone Creek is underlain by shallow deposits of gravel, sand, and some finer sediments historically laid down by the creek. Such materials contain water percolated from seasonal creek flows. This groundwater is tapped at present along Chalone Creek by two park supply wells. Small springs issue from openings in the harder volcanic and igneous rocks in places around the area. Located east of Chalone Creek, sedimentary fanglomerate of the Temblor Formation have been identified by others as possibly possessing some water well potential to supply park needs.

The principal geologic formations in this locality are shown in Figure 1 along with the Chalone Fault and the position of the refraction geophysical profile. The geology shown was adopted from previous investigations by the U.S. Geological Survey (USGS) and others.

### 1.2 Previous Work

The Pinnacles area was included in previous geologic mapping by Andrews (1936), Evensen (1962), Akers (1972), and by T. W. Dibblee Jr., (1969), (1975), (1979) and (1980), available as open-file USGS maps. These investigations delineated the trace of the Chalone Creek Fault,

as well as outcrop areas of major rock units. In 1962, the USGS (Evenson) made a reconnaissance of groundwater potential at the Pinnacles Monument area. This was followed by a later USGS groundwater reconnaissance in 1967 by J. Akers which updated previous work and recommended certain test well exploration. In the 1930's the Civilian Conservation Corp. (CCC) constructed a hand-dug well in the channel gravels along Chalone Creek above the Chalone Creek Campground and produced water from it for a limited time, but it was later destroyed. In 1959, a well was drilled downstream, roughly opposite the campground, and put into use. This well was not a satisfactory producer, attributed to excessive input of drilling mud, and a new well was later drilled nearby, which is in use at present. Subsequently, a similar well in the creek alluvium was drilled (1968) downstream near the Chalone/Bear Creek confluence shown as location 1F1 on Figure 1. It is known as the YAAC well and considered as "nonpotable." To preliminarily explore the Temblor fanglomerate east of the Chalone Creek Fault, a test well was drilled into that formation, also in 1968, within the Chalone Creek Campground. This test went to a depth of 480 feet but did not encounter usable amounts of groundwater and was abandoned.

## 2.0 GEOLOGICAL INVESTIGATION

The field portion of the current geologic investigation focused on observing the Chalone Creek Fault and the type of rocks found on both sides of the fault throughout the study area. It was observed that a good deal of the length of the Chalone Creek Fault trace is obscured by soil, brush, and in the creek channel, by alluvium. Changes in rock-type across the previously mapped position of the fault were observable throughout the area of investigation. Aerial photographs were very useful in supplementing ground examinations of the position of the fault and in delineating rock types on either side of it. The geology shown on Figure 1 is essentially as reported by Akers (1967) with the exception that the position of the Chalone Creek fault in the general vicinity of ($A$-$A^1$) is based on the results of the refraction geophysical data. The fault plane/zone marks the boundary or contact between rhyolite (Tr) on the west and fanglomerate of the Temblor formation (Tmt) on the east. At this location, the fault is concealed by approximately 20 feet of stream-deposited alluvium (Qal).

The projected buried trace of the fault beneath the stream deposited gravels was traversed by foot throughout the fault length shown in Figure 1. Outcrops on either side of the Chalone Creek channel were observed for a distance of approximately three miles north of the confluence with Bear Creek and approximately one mile south of the confluence. Highly fractured rhyolite was observed in the stream channel south of the Bear Creek, confluence and a large spring was observed. Granite outcrops (g), as mapped by Akers (1967) were not apparent, however, granite boulders were observed to be common in the top soil and also as cobbles in the stream channels.

The Chalone Creek steambed and channel floor were observed to extend some 2,500 feet to the southeast beyond the entrance to Bear Valley, thus the Chalone-Bear Creek confluence is far beyond the actual intersection of the two valleys. The reason for this unique and anomalous condition was not apparent in this reconnaissance, but is undoubtedly caused by historical tectonic changes which likely relate to movement along the Chalone Creek Fault.

## 3.0 CHALONE CREEK FAULT LOCATION

The Chalone Creek Fault, as determined by field inspection and by a refraction geophysical survey (Appendix), is shown on Figure 1 and on Cross Section A-A[1] in Figure 2.

The fault is east of the gravel pit and is concealed by approximately 20 feet of alluvium in the Chalone Creek channel at the location of the refraction geophysical traverse. As indicated above, the location of the fault is interpreted to be the contact between rhyolite on the west and the Temblor Formation on the east. A zone of either faulted and fractured rhyolite, or fanglomerate, extends for approximately 225 feet east of the fault.

Eastward beyond the faulted and fractured zone, fanglomerates of the Temblor Formation extend for a considerable distance.

The angle of dip of the fault is to the east and estimated to be approximately 60 degrees from the horizontal. The angle of dip was determined from outcrop locations as mapped at the surface and as encountered in the 1968 Temblor Formation bore hole in the Chalone Creek Campground.

## 4.0 PLANNED TEST HOLE IN TEMBLOR FORMATION

It has been recommended by others that as a follow-up to the 1968 exploratory test well in the Temblor Formation east of the Chalone Creek Fault, another Temblor test well be drilled some distance "downfault" to the southeast where the hydrogeologic character of the Temblor Formation may be significantly different and more conducive to well production. Inasmuch as the Chalone Creek Fault has been determined to dip toward the east, it is necessary for the new test well site to be a sufficient distance east of the fault in order to provide an adequate test depth of Temblor. If an adequate test thickness of Temblor for well water drilling purposes is assumed to be 600 feet, then the site of a new test hold should be northeast of the line marked B-B[1] in Figure 1, based on available data. The fanglomerate deepens toward the northeast away from the fault. The area from approximately 50 feet east of the road and the end of the geophysical traverse where the line marked B-B[1] is located is covered by soil and alluvium. This would also be a satisfactory area in which to drill a test well and is above the influence of flow from Chalone Creek.

Based on the results obtained during this investigation, it would appear that the most favorable site for the new test well is east-northeast of the existing YACC well (17S/7E-1F1) in the general area indicated in Figure 1. This area is suggested because of its considerable distance from the earlier Temblor test well, and the associated potential for encountering better hydrologic properties, and also because of the area's accessibility by drilling equipment.

Prospects for obtaining a usable quantity of water in the Temblor Formation in this area are uncertain, but certainly significant. Left unexplored, a possible valuable source of groundwater for park use might go undiscovered and thus undeveloped. Water obtained from such an aquifer removed from stream influence has the advantage of not requiring treatment for human consumption in park usage.

## 5.0 OTHER POTENTIAL GROUNDWATER SOURCES

Based on local well experience to date, plus the geophysical profiling in the current investigation, reasonably predictable opportunities for obtaining additional well supplies in the immediate vicinity of the Chalone Creek Fault appear limited to creek alluvium (Qal, Figure 1).

Volcanic and granitic rocks, which comprise the vast part of the Pinnacles Monument area, contain some water in places within fractures and fissures, as expressed in a number of local spring issuances. However, such sources are by nature limited and often unreliable. Exploring well prospects in these rocks would be essentially random and expensive. Fault zones often contain crushed rock in which water accumulates. Two wells on the west side of the park tap such water in the Pinnacles Fault zone. Such occurrences are not common; however, the 1968 test well in the Temblor Formation intersected the Chalone Creek Fault but found it devoid of water. Drill sites could be located based on geologic analysis to intersect park fault zones at depth, however, such a program would be expensive and of questionable justification.

Certain sedimentary formations which are important aquifers elsewhere extend to within possibly reasonable piping distance of the Pinnacles. Such aquifer units can be considered as good potential sources of well supplies to the park if other development factors were found feasible.

## 6.0 REFERENCES


Akers, J.P. (1967). The Geohydrology of Pinnacles National Monument, California, 14 pp., map 1:31, 680, USGS Open-File Report, Menlo Park, CA, Nov. 14.

Andrews, Philip (1936). Geology of the Pinnacles National Monument, CA, Univer. Dept., Geol. Sci. Bull. Y.24, NO. 1, pp. 1-38, map 1:31,680.

Dibblee, T. W., Jr. (1969). Geologic Map of the Greenfield Quadrangle, CA, USGS Open-file Map, 1:62,500.

Dibblee, T. W., Jr. (1975). Geologic Map of the San Benito Quadrangle, California, USGS Open-file map, 1:62,500.

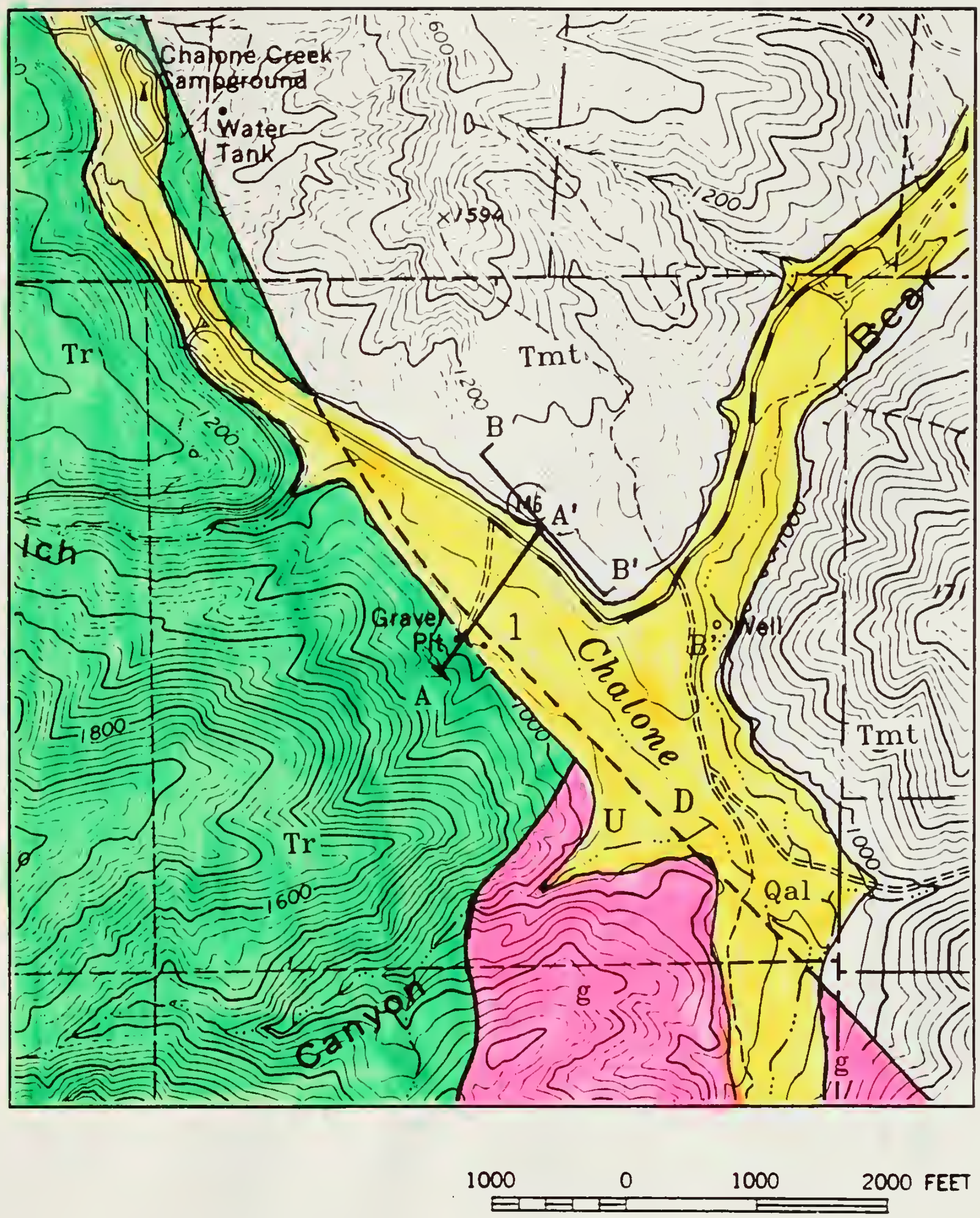
Dibblee, T.W., Jr. (1979). Geologic Map of the Bickmore Canyon Quadrangle, CA, USGS Open-file map, 1:24,000

Dibblee, T. W., Jr. (1980). Geology Along the San Andreas Fault from Gilroy to Parkfield, pp. 3, 10, 12, and 15 in California Div. of Mines and Geology Special Report 140, R. Streitz and R. S. Sherluerne, editors.

Evensen, R. E. (1962). Groundwater Reconnaissance at Pinnacles National Monument, California, USGS WSP 1475-K, 22p., map 31,680.

Ross, D. C., (1972). Geologic Map of the Pre-Cenozoic Basement Rocks, Gabilan Range, Monterey and San Benito Counties, CA, USGS Map MF-357, 1:125,000.

# FIGURES




EXPLANATION

Qal = Alluvium; Sand and Gravel

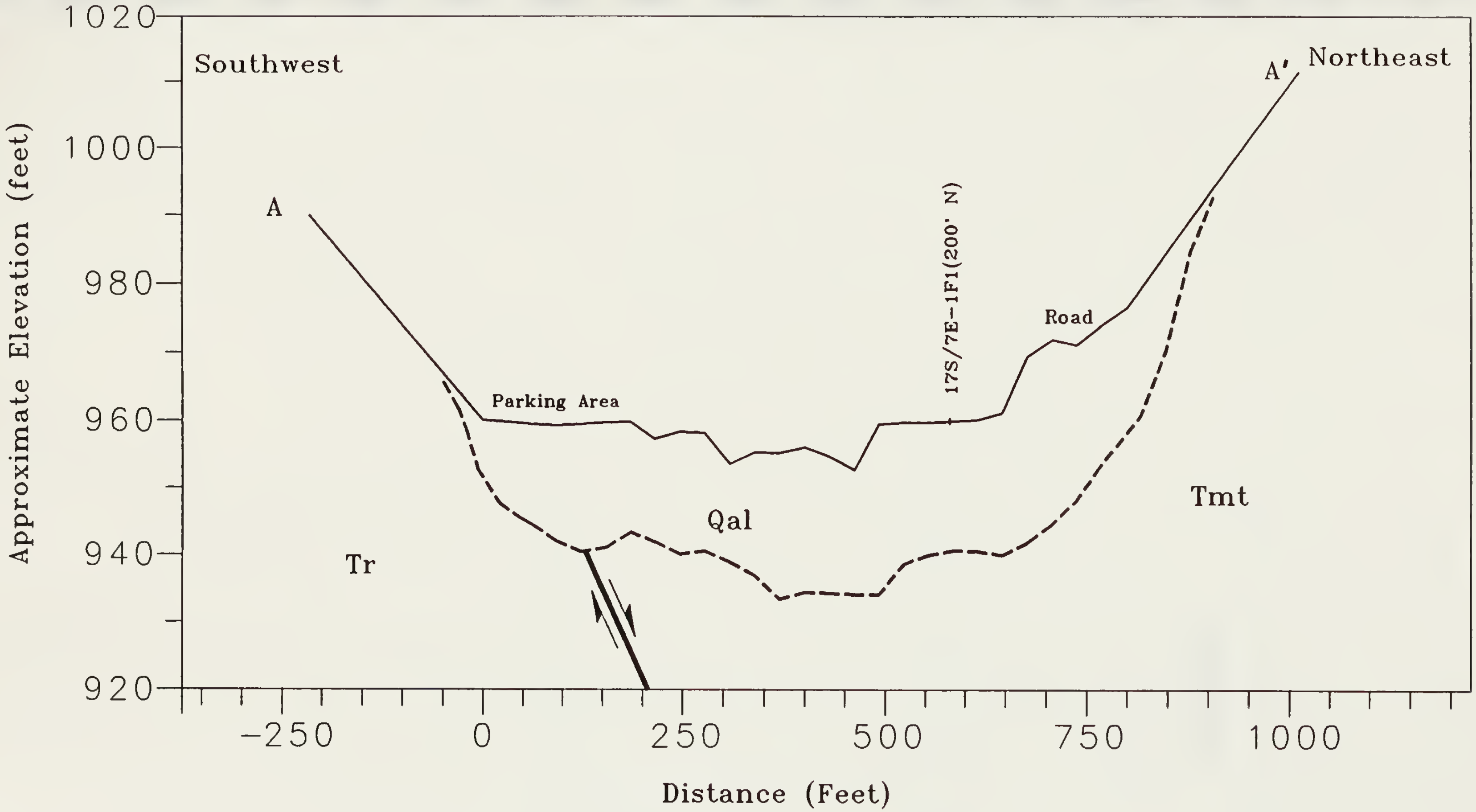
Tmt = Tremblor Formation
Fanglomerate grading upward into gravel and diatomaceous shale

U\D = Chalone Fault

Tr = Rhyolite
Massive and laminated flows; also some andesite and basalt

g = Granitic rocks
Principally granodiorite, include som granite and gneiss and locally intruded by rhyolite porphyry dikes and sills

FIGURE 1. GEOLOGIC MAP OF THE PINNACLES NATIONAL MONUMENT AREA IN THE VICINITY OF CHALONE AND BEAR CREEK CONFUENCE.




EXPLANATION

Chalone Fault

Qal = Alluvium; Sand and Gravel

Tmt = Tremblor Formation
Fanglomerate grading upward into gravel and diatomaceous shale

Tr = Rhyolite
Massive and laminated flows; also some andesite and basalt

Note: See Figure 1 for location of the cross section

FIGURE 2. GEOLOGIC CROSS SECTION ACROSS CHALONE CREEK, PINNACLES NATIONAL MONUMENT

# APPENDIX

J R ASSOCIATES

Engineering Geophysics
1886 Emory Street
San Jose, CA 95126
(408) 293-7390

# SEISMIC REFRACTION SURVEY AT THE PINNACLES NATIONAL MONUMENT
# SAN BENITO COUNTY, CALIFORNIA

August 17, 1993

for

F. R. Conwell and Associates
1641 North First Street, Suite 235
San Jose, California 95112

by

James Rezowalli, GP-921

# TABLE OF CONTENTS

# LIST OF ILLUSTRATIONS

# I INTRODUCTION

This report presents the results of a seismic refraction investigation performed at the Pinnacles National Monument for F. R. Conwell and Associates. The purpose of the investigation was to determine seismic layering, rock velocities, and help locate a contact between two rock formations. This information will aid in locating a water well for the Monument. James Rezowalli, Tom Barry, and Lanbo Liu of J R Associates performed the field work on August 11, 1993. We wish to express are thanks to the National Park Service's personnel who provided us assistance during the investigation.

## A. Site

The Pinnacles National Monument is approximately 31 miles south of Hollister, California. We performed the seismic refraction investigation in an area crossing the Chalone Creek. This area is approximately 1 mile from the Monument's eastern boundary on Highway 146 (Drawing 1). F. R. Conwell and Associates provided us information showing the Chalone Creek Fault lying beneath the area investigated. The fault strikes roughly N30°W and dips to the east. The fault marks a contact between rhyolite on the west side of Chalone Creek and fanglomerate on the east side of Chalone Creek.

Presently the Monument gets its drinking water from a well located near the old Chalone Creek campground, approximately two miles from the Monument's eastern boundary on Highway 146. National Park Service plans call for drilling a new water well in the fanglomerate in the area we investigated. The purpose of the refraction investigation is to help locate the contact

between the rhyolite and the fanglomerate. The well can then be drilled far enough away from the contact to avoid encountering the rhyolite at depth.

between the rhyolite and the fanglomerate. The well can then be drilled far enough away from the contact to avoid encountering the rhyolite at depth.

# II METHODOLOGY

Often there is a measurable difference in compressional wave (P-wave) velocities of two different rock formations. At the Pinnacles, we suspect the rhyolite has a faster P-wave velocity then the fanglomerate. The refraction data was used to measure the depth and P-wave velocities of the bedrock beneath Chalone Creek and across the Chalone Creek Fault. A change from a higher velocity on the west side of the creek to a lower velocity on the east side of the creek would be an indicator of the contact between the rhyolite and the fanglomerate.

## A. Field Procedures

Refraction data were collected along an 800 foot refraction line (Drawing 1). The refraction line contained 24 evenly spaced geophones and 7 shot points. Shot points were located 215 feet off the ends of the line, at the ends of the line, and along the line. Five of the shots consisted of 1/3 pound charges of an ammonium nitrate based explosive. The explosives were buried 2 feet beneath the ground surface. A hammer and plate were used for the remaining two shots.

## B. Instrumentation

We used 14 Hz geophones to detect the seismic signals. A cable connected the geophones to two Geometrics, Incorporated, signal enhancement seismographs. The seismographs collected and recorded the signals. A CRT displayed the seismograph recordings in the field for quality control and a strip chart recorder printed permanent records.

C. Data Reduction

Data reduction began by picking the arrival times from the seismograph recordings. An arrival time is the time a P-wave spent travelling from shot point to geophone. The wave could either travel along the ground surface or be refracted from an interface between materials. For a refraction to occur, the materials below the interface must have a greater P-wave velocity than the materials above the interface. The arrival times were entered into a computer program with elevation, location, and layer control information. Elevation changes along the refraction line were measured with a hand level and the absolute elevation at one end of the line was obtained from a USGS topographic map.

Two different interpretation techniques were used to evaluate the refraction data. The first technique used the generalized reciprocal method (GRM) of interpretation[1]. The GRM is a technique for profiling the top of subsurface refracting layers and for determining the P-wave velocity along subsurface refracting layers. It is relatively insensitive to topography and refractor dip angles. Its ability to measure P-wave velocity changes in a refracting horizon makes it particularly useful for finding geologic contacts beneath the ground surface.

The second method used the interpretation program, FSIP. FSIP performs a first approximation delineation of refracting horizons using a delay-time method. The approximation is then tested and improved by the program's ray-tracing procedure in which ray travel times computed for the model are compared against field-measured travel times. The model is subsequently adjusted in an iterative manner to minimize the discrepancy between the

[1]Palmer, D., 1981, An Introduction to the Generalized Reciprocal Method of Seismic Refraction Interpretation: Geophysics, v. 46, p. 1508-1518.

computed and measured travel times. A Bureau of Mines Report of Investigation describes the program[2].

[2]Scott, James H., Computer Analysis of Seismic Refraction Data, BuMines RI 7595, 1972.

computed and measured travel times. A Bureau of Mines Report of Investigation describes the program[7].

[7] Scott, James H., Computer Analysis of Seismic Refraction Data. BuMines RI 7595, 1972.

## III RESULTS

The results of the analysis of the refraction data are presented in Drawings 2 through 4 and Table 1. The drawings show the seismic layering, the layer velocities, and the location of the fault based on the data. Table 1 summarizes the results presented in the drawings.

Table 1. Summary of Refraction Results

| Line | Depth to Refracting Layer (feet) | Fluvial Deposit Velocity (fps) | Bedrock Velocity (fps) |
|---|---|---|---|
| 1 | 11 to 30 | 1000 to 1400 | 7500 to 9000 |

A. Seismic Layering

Drawing 2 is a two dimensional diagram showing the depth to bedrock beneath Chalone Creek. The two dashed lines show the depth to bedrock based on the two different methods we used to analyze the data. Both methods indicated the depth to the bedrock ranges from 11 to 30 feet beneath the ground surface. The possible fault zone shown on Drawing 2 was obtained from a velocity analysis described next.

B. Seismic Velocities

Drawing 3 shows the P-wave velocities measured beneath the refraction line. The solid line shows the velocities of the fluvial material deposited by Chalone Creek. The velocity of the creek deposits range from 1000 to 1400

feet per second (fps). This range in velocity is typical of dry to partially saturated loose sediments.

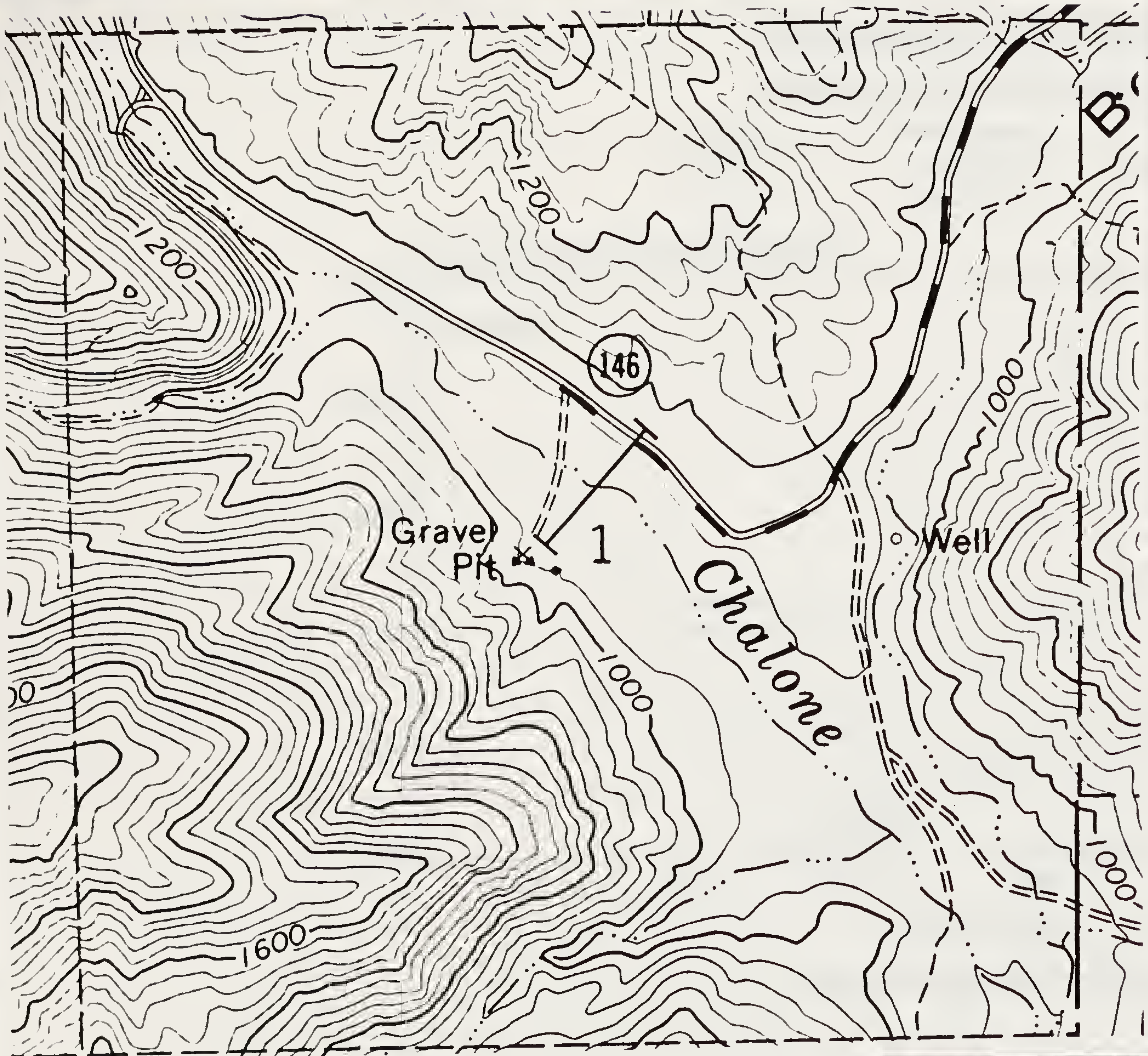
The dotted and dashed lines show the velocity of bedrock beneath the creek deposits. The dotted and dashed lines represent results based on two runs of the GRM program. For the first run, we assumed there would be a rapid drop in P-wave velocity as we crossed from rhyolite on the west side of the fault to the fanglomerate on the east side of the fault. The dotted line on Drawing 3 was obtained using this assumption. For the second run, we assumed a gradual change in velocity across the fault. The dashed line on Drawing 3 was obtained using this assumption. The velocity profiles obtained from the two runs suggested the fault lies somewhere between 120 feet and 400 feet from the start of the line. The most likely location is 150 feet from the start of the line. This is where we found the greatest contrast in P-wave velocity. Drawing 4 show the location of the fault based on the refraction results.

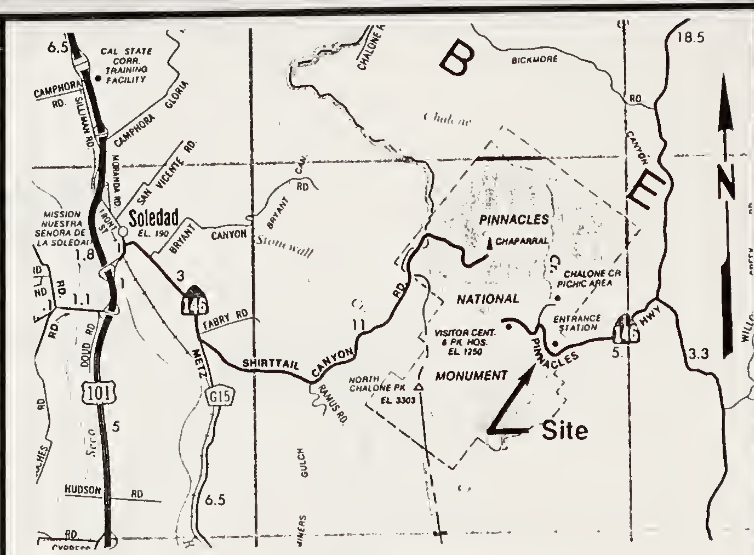
The velocity of the fanglomerate, approximately 7500 fps, indicates it is highly indurated. Typically unfractured rocks with velocities above 7000 fps are not good water producers.

## C. Limitations

Seismic layers do not always correspond directly to lithologic changes that might be found in borehole or trenching data. A seismic layer is an interface between materials with different P-wave velocities. Factors such as weathering, cementation, fracturing, and saturation, as well as lithologic change can create changes in seismic velocities. Also there can be lithologic changes without velocity changes. However, our field experience indicates that seismic layers often correspond to major changes in lithology or saturation to within ±20% of the depth to the interface.

# IV DRAWINGS

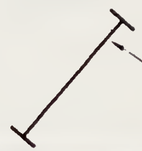



**Site**

No Scale

EXPLANATION:




**Vicinity Map**
Pinnacles National Monument
San Benito County, California

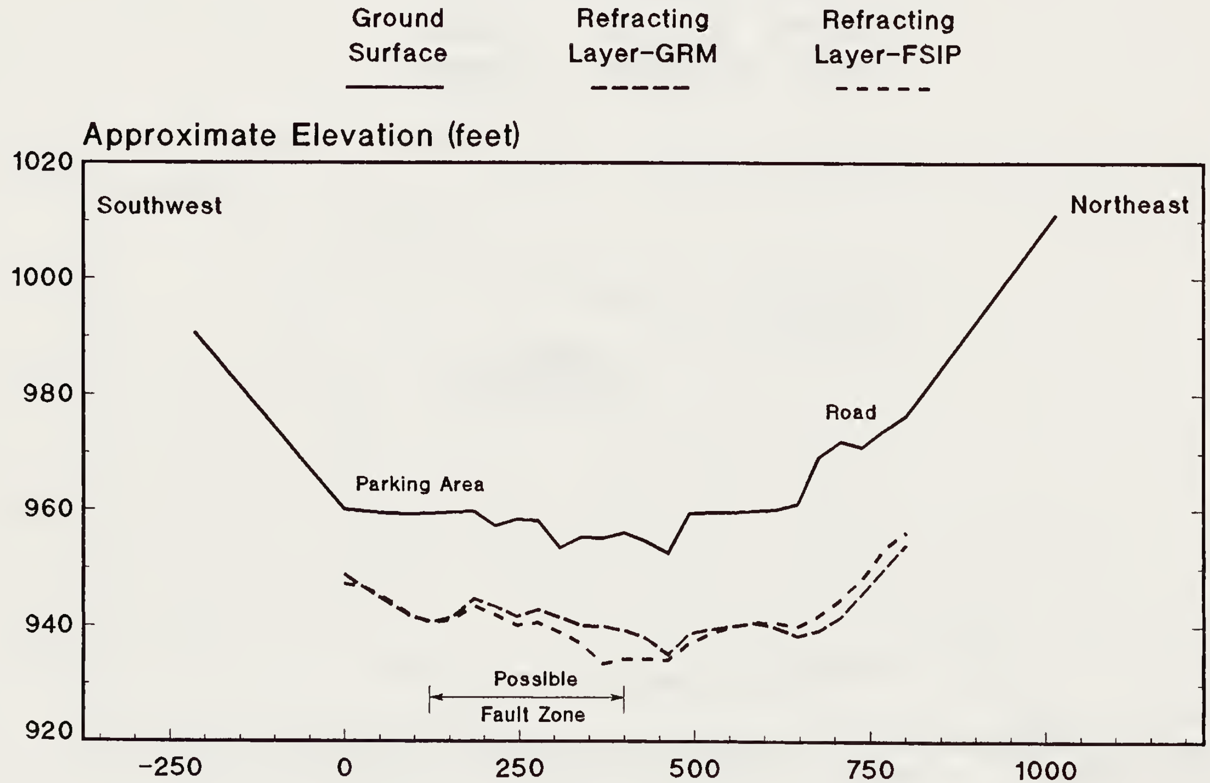
| | | |
|---|---|---|
| SCALE: 1" = 1000' | APPROVED BY: | DRAWN BY J.J.R. |
| DATE: August 17, 1993 | Job Number: 057127-93 | REVISED |

**J R ASSOCIATES** Engineering Geophysics
1886 Emory Street, San Jose, CA 95126 (408) 293-7390

| | |
|---|---|
| Note: Base map modified from USGS North Chalone Peak Quadrangle topographic map. | DRAWING NUMBER 1 |

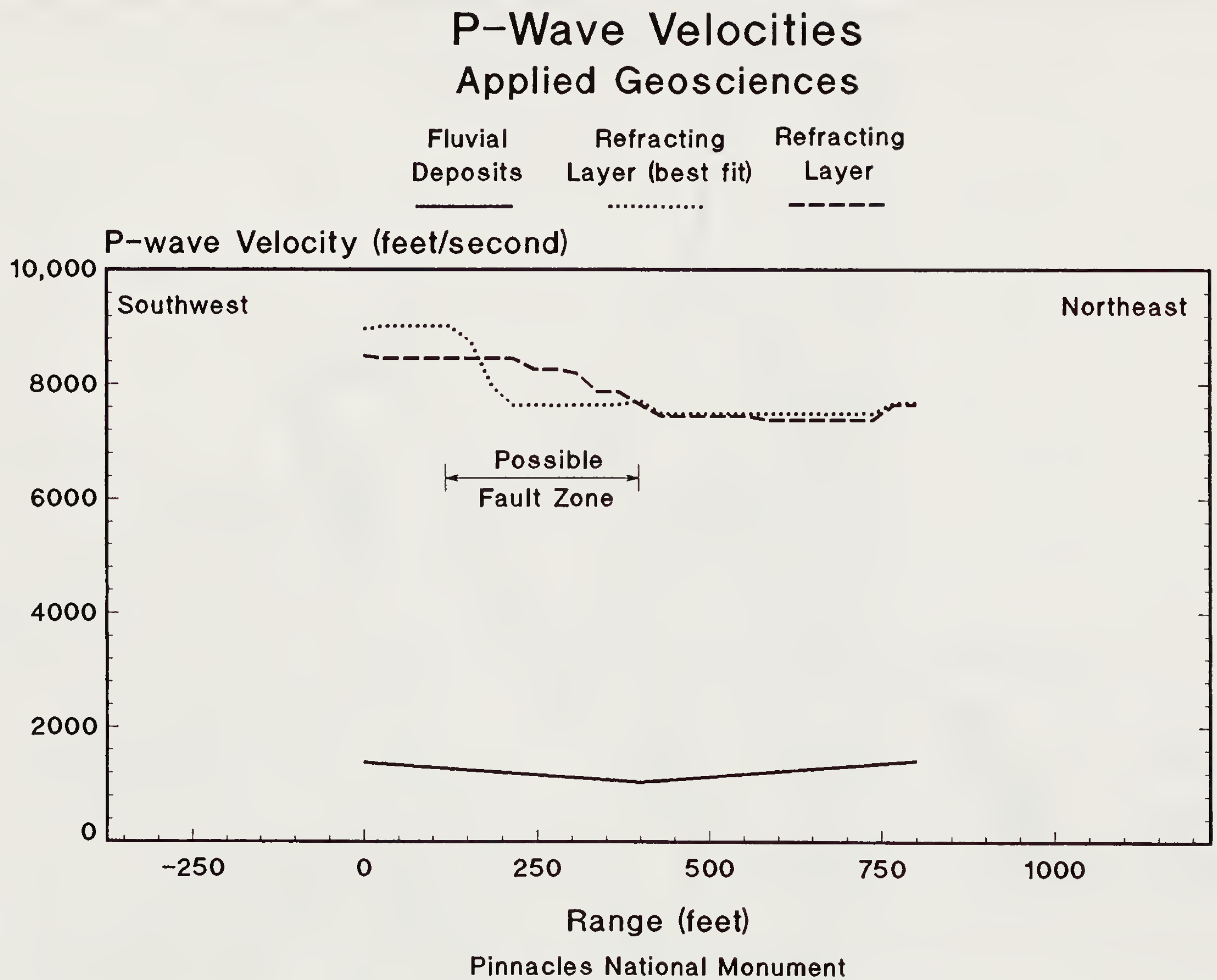
# Refraction Profile

## Applied Geosciences



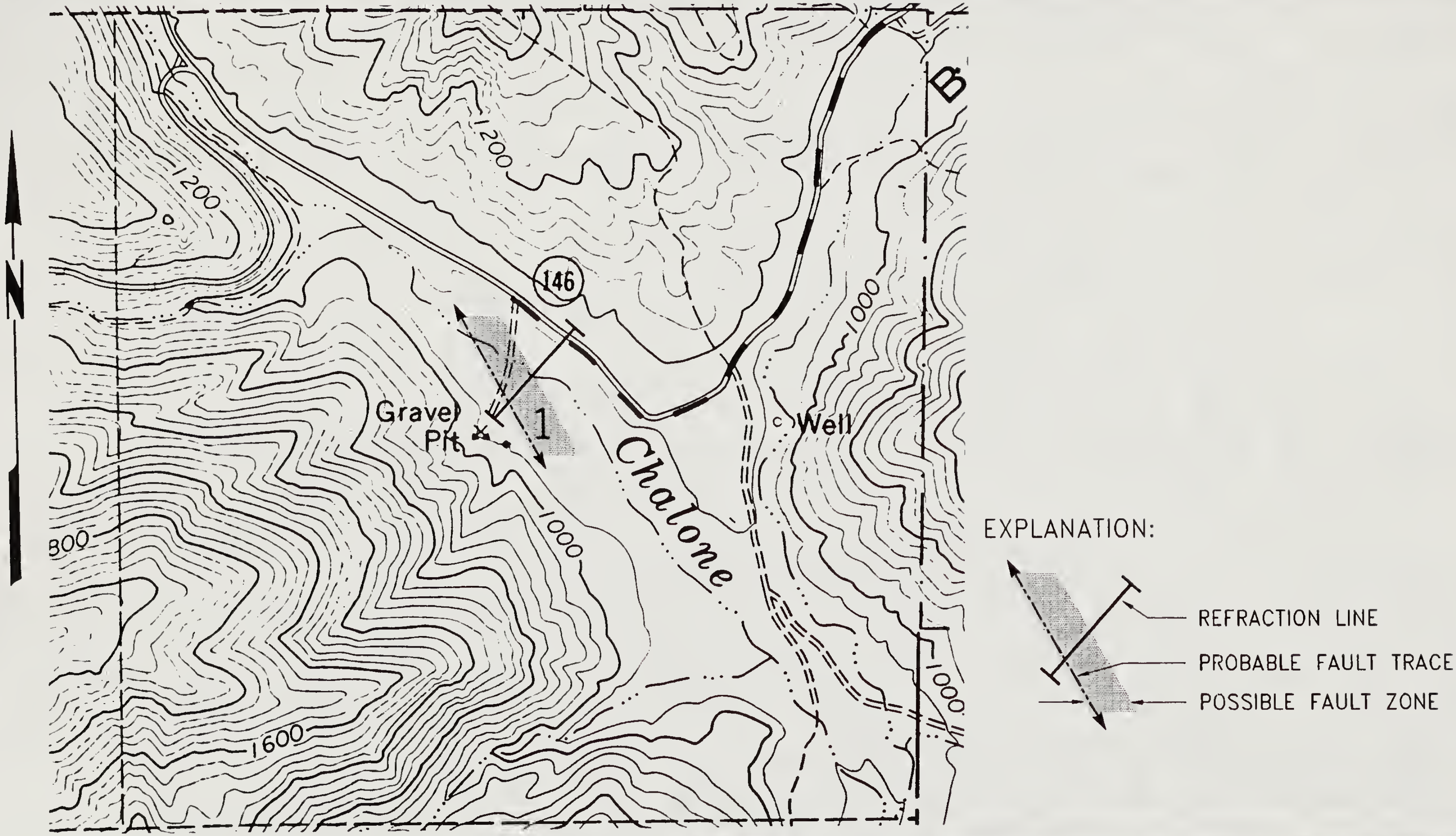

Pinnacles National Monument

| | | |
|---|---|---|
| **Refraction Profile**<br>Pinnacles National Monument<br>San Benito County, California | | |
| SCALE: See Diagram | APPROVED BY: | DRAWN BY J.J.R. |
| DATE: August 17, 1993 | Job Number: 057127-93 | REVISED |
| **J R ASSOCIATES** Engineering Geophysics<br>1886 Emory Street, San Jose, CA 95126 (408) 293-7390 | | |
| | | DRAWING NUMBER<br>**2** |




| | | |
|---|---|---|
| **P-wave Velocity Profile**<br>Pinnacles National Monument<br>San Benito County, California | | |
| SCALE: See Diagram | APPROVED BY: | DRAWN BY J.J.R. |
| DATE: August 17, 1993 | Job Number: 057127-93 | REVISED |
| **J R ASSOCIATES** Engineering Geophysics<br>1886 Emory Street, San Jose, CA 95126 (408) 293-7390 | | |
| | | DRAWING NUMBER **3** |

8½ X 11 PRINTED ON NO. 1000H CLEARPRINT ®




**Refraction Investigation Results**
Pinnacles National Monument
San Benito, California

| | | | |
|---|---|---|---|
| SCALE: 1" = 1000' | APPROVED BY: | DRAWN BY J.J.R. | |
| DATE: August 17, 1993 | Job Number: 057127-93 | REVISED | |

**J R ASSOCIATES** Engineering Geophysics
1886 Emory Street, San Jose, CA 95126 (408) 293-7390

DRAWING NUMBER
**4**